Howard Hanson Dam
Additional Water Storage Project Phase I

Habitat Restoration Zone One Biological Monitoring

Final Data Report

Prepared for:

U.S. Army Corps of Engineers, Seattle District

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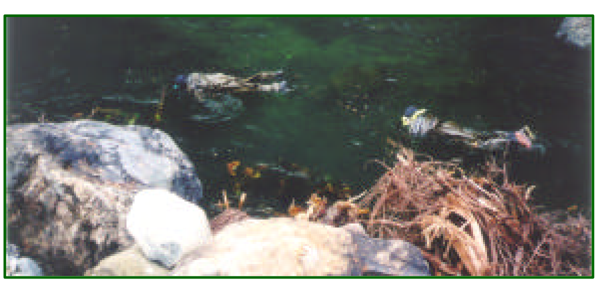
March 2004



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March 2004 1414.01

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1. INTRODUCTION

1.1 BACKGROUND

The U.S. Army Corps of Engineers, Seattle District (USACE) and the City of Tacoma (Tacoma) are currently involved in Phase I of the Howard Hanson Dam (HHD) Additional Water Storage Project (AWSP) (USACE 2000). The USACE completed construction of the HHD at RM 64.5 in 1962. The Project is currently operated to provide winter and spring flood control as well as enhancing summer low flow augmentation for fish resources. During spring months, HHD switches from flood storage to its secondary role of conservation storage for low flow augmentation. The existing reservoir provides for 25,400 acre-feet (ac-ft) of summer/fall storage; 24,200 ac-ft is active storage available for enhancing instream flows below the project.

In the future, the AWSP will provide up to an additional 37,000 ac-ft over existing storage by raising the existing summer conservation pool by 36 feet (from 1,141 feet to 1,177 feet). The AWSP will be implemented in two phases. During Phase I, a fish passage facility will be constructed at the dam and storage will be increased by up to 25,000 ac-ft, (up to 20,000 ac-ft of which will be stored for municipal water supply). Phase I also includes the option to store up to 5,000 ac-ft of water for low flow augmentation purposes to benefit downstream fishery resources. In Phase II, an additional 12,000 ac-ft of storage will be added to the Phase I conditions (9,600 ac-ft will be available for fisheries, and 2,400 ac-ft will be available for municipal and industrial water supply) (Table 1).

Table 1. Comparison of Howard Hanson Dam summer conservation pool between the existing project and the AWSP Phase I and Phase II.

	Summer Conservation Pool	
Project Condition	**Volume**	**Elevation**
Existing HHD Project	25,400 ac-ft (normal year)	1,141 ft
AWSP Phase I	50,400 ac-ft	1,167 ft
AWSP Phase II	62,400 ac-ft	1,177 ft

Under Phase I of the HHD-AWSP, up to an additional 20,000 ac-ft of municipal and industrial water will be stored in the spring for release during the summer and fall. Phase I will include all structural features required to provide a downstream fish passage facility at HHD, as well as several habitat restoration and mitigation projects. Habitat restoration/mitigation projects associated with Phase I include:

- Downstream fish passage facility constructed at HHD;
- Flow releases to benefit aquatic instream resources;
- Management of riparian forests to maintain forest succession on major streams upstream from HHD;
- Reconnection of side-channel habitat to the mainstem middle Green River;
- Habitat rehabilitation including large woody debris (LWD) or engineered log jam (ELJ) placement and excavation or reconnection of off-channel habitats to selected streams reaches;
- Annual release of gravels to the Green River; and
- Transport and/or placement of woody debris in the Green River.

Under the AWSP Phase I activities, the USACE intends to construct engineered logjams and place gravels as a Pilot Project in the Kanaskat – Palmer reach of the Green River. The ELJs are intended to restore ecological function by providing habitat created by logjam systems. The ELJs will create additional habitat in part through the creation of scour pools by trapping large woody debris and gravels (TetraTech 2003a). Gravel will also be introduced into the river from a series of loading zones. The goal is to trap and store gravel in areas that will be beneficial to spawning salmonids and thereby restore ecological functions to the river. All Phase I restoration/mitigation projects will be monitored after implementation, and some of the activities require pre-construction studies and/or monitoring.

Two restoration zones were identified to implement construction of engineered logjams and gravel placement (Figure 1). Restoration Zone 1 is located entirely within property owned by Tacoma and the Washington Department of Natural Resources at RM 60. Restoration Zone 2 encompasses lands owned by King County and surrounding private properties near the Tacoma pipeline crossing located near RM 58. Since Tacoma is the local sponsor to the AWSP, construction in Restoration Zone 1 occurred in August 2003. Restoration Zone 2 has been identified as a possible site for future habitat restoration measures in the Green River.

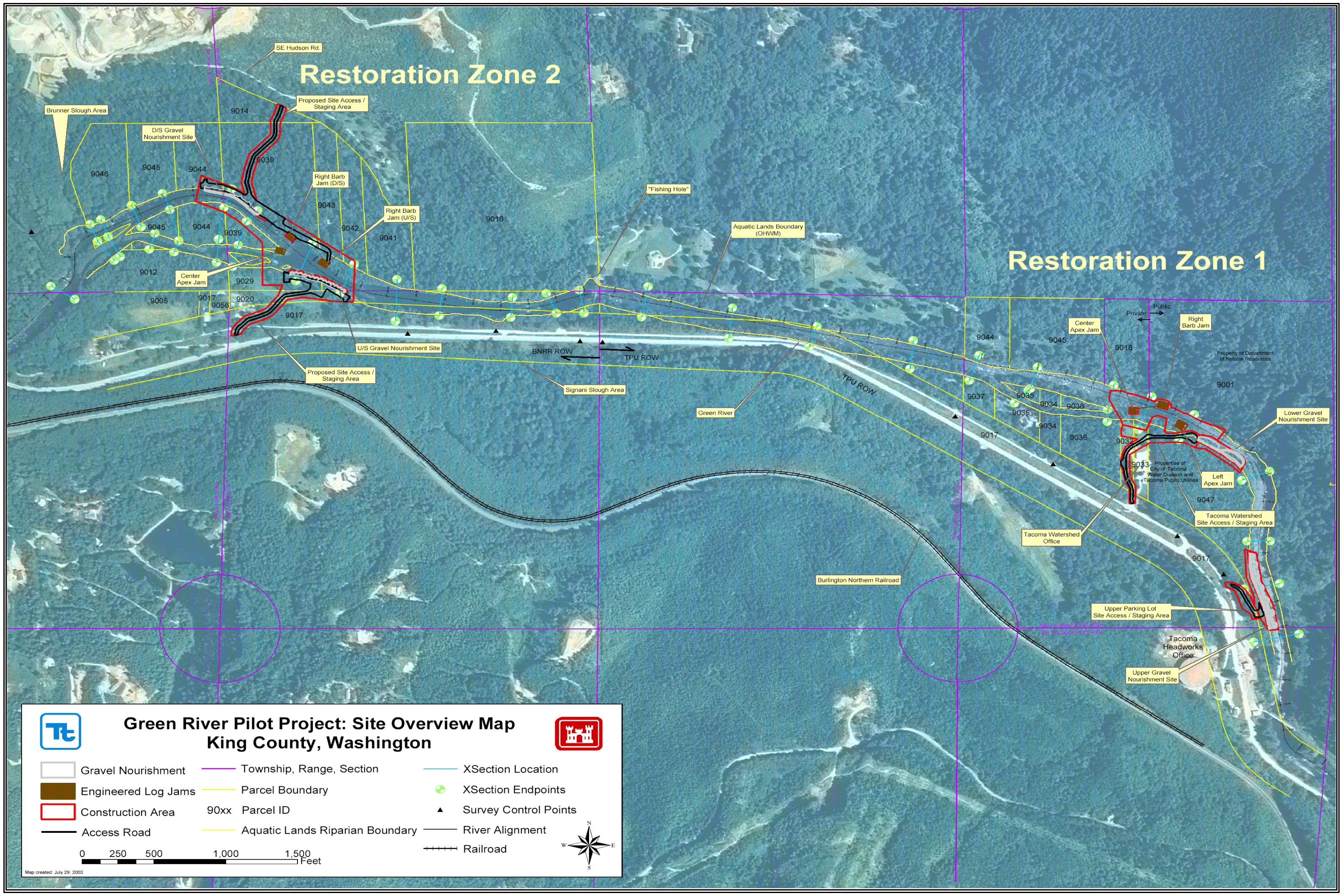

Figure 1. Location of Restoration Zones 1 and 2, upper Green River, King County, Washington (adapted from USACE by R2 Resource Consultants 2003).

1.2 FISH RESOURCES

The Green River, Washington, supports a wide array of salmonid species, each with a slightly different life history strategy. Populations of sockeye (*Oncorhynchus nerka*), coho (*O. kisutch*), chinook (*O. tshawytscha*), and chum (*O. keta*) salmon, cutthroat (*O. clarki*) and steelhead (*O. mykiss*) trout, and mountain whitefish (*Prosopium williamsoni*) are present in the system in varying numbers; pink salmon (*O. gorbuscha*) are occasionally found, but not in large numbers. Historically, bull trout (*Salvelinus confluentus*) have been reported to occur in the Green River (Grette and Salo 1986). In the last 50 years, no juvenile bull trout have been reported in the Green River basin; however, solitary adults have been observed periodically in the lower river (F. Goetz, USACE, pers. comm.).

The general life history of Pacific salmon involves constructing nests (redds) in gravel beds for spawning, followed by migration to the ocean for feeding and maturation, and returning to natal sites for spawning and completion of their life cycle (i.e., anadromy) (Meehan and Bjornn 1991). The anadromous life cycle employed by many members of the subfamily Salmoninae appears to have originated while the fish resided in freshwater and allows them to benefit from favorable habitats of two quite different systems (Randall et al. 1987; Wilson 1997). There are many variations on the timing and duration of these life cycles both between species, and year to year for the same species. Each salmonid species present in the Green River has a different length and timing of freshwater residence (Figure 2). Understanding the respective life history characteristics of Green River salmonids will assist water managers to identify and implement restoration/enhancement strategies to maximize the benefits to fish inhabiting the Green River.

For example, fall chinook generally spawn during early September through November. Like other salmonids, the duration of incubation varies with location of redds, timing, egg size, and water temperature, but is generally completed by the end of February or early March (Weatherly and Gill 1995). Young chinook reside in stream gravels as alevins for three to six weeks after hatching (Wydoski and Whitney 1979; Beauchamp et al. 1983) before moving to lateral stream habitats (e.g., sloughs, side channels, and pools) for refugia and food during their migration downstream to the estuary. Fry emerge from gravels in late February through April, while downstream migration of newly-emerged fry peaks between 7 April and 17 April in the Green River (Dunstan 1955; Hilgert and Jeanes 1999, Jeanes and Hilgert 2000). Chinook alevins generally spend more time residing in the gravels before emergence, and are typically larger than other Pacific salmon upon emergence (Weatherly and Gill 1995).

Coho alevins spend three to four weeks (depending on food stored in the yolk sac) absorbing the yolk sac in the gravels of the redd before they emerge (Meehan and Bjornn 1991; Sandercock 1991). Coho begin to emerge approximately one month later than chinook, in early March to mid-May (McMahon 1983; Laufle et al. 1986). Juvenile coho salmon rear in freshwater for approximately 15 months prior to migrating downstream to the ocean, but may extend their freshwater rearing time for up to two years (Meehan and Bjornn 1991; Weitkamp et al. 1995). Complex woody debris structures and side channels are important habitat elements for juvenile coho salmon, particularly during the summer low-flow period on the Green River (Grette and Salo 1986; McMahon 1983; Peters 1996). During studies conducted in 1998, newly-emerged coho (e.g., yolk sac fry) were initially found in the middle Green River on 25 February (Hilgert and Jeanes 1999). Coho fry continued to be present through May, with peak relative abundance occurring in mid-April (Hilgert and Jeanes 1999). As juveniles grow, they move into faster water and aggressively defend their territory, resulting in the displacement of excess juveniles downstream to less favorable habitats (Chapman 1962; Wydoski and Whitney 1979; Sabo 1995; Sabo and Pauley 1997). Aggressive behavior by juvenile coho may be an important factor that maintains the numbers of juveniles within the carrying capacity of the stream (Chapman 1962; Chapman 1966).

In comparison to coho, juvenile chum and pink salmon have an "ocean-type" early life history, rearing in freshwater for only a few days to a few weeks before migrating downstream to saltwater (Grette and Salo 1986; Heard 1991; Salo 1991; Johnson et al. 1997). Chum fry that migrate to sea within several days after emergence exhibit little growth, while fry that rear for longer periods may exhibit an increase in length up to 22 percent in less than four weeks (Hale et al. 1985). Downstream movement in the Green River occurs through late May, but varies annually. Dunstan (1955) captured an initial surge of chum fry in late February, but believed the peak outmigration of chum fry occurred between March 20 and April 3. Chum fry displayed bimodal peaks in emigration occurring on 1 May and 15 in the Elwha River, Washington (Peters 1996). Some freshwater rearing is thought to occur in the middle Green River based on recapture information and increasing mean lengths of chum during a spring 1998 and 1999 study period (Hilgert and Jeanes 1999; Jeanes and Hilgert 2000).

Juvenile steelhead incubation rates vary according to numerous biotic and abiotic factors and require a relatively short incubation period compared to other salmonids. Fry emergence typically occurs from 30 to 60 days after spawning (Pauley 1986). Hilgert and Jeanes (1998) first observed newly emerged steelhead fry in the Green River in late May. Steelhead juveniles rear in freshwater for one or more years before migrating to the ocean (Peven 1990; Busby et al.

1996). In the Green River, most juvenile steelhead emigrate after two years rearing in freshwater (Meigs and Pautzke 1941). An early study of steelhead smolt emigration by Pautzke and Meigs (1940) found that steelhead smolts emigrated from the Green River primarily during April and May. In general juvenile downstream migration for steelhead smolts in Puget Sound occurs from April through June, with peak migration occurring in mid-April (Wydoski and Whitney 1979). Steelhead in smolt condition were captured during juvenile surveys in the middle Green River during the month of May in 1998 1999 (Hilgert and Jeanes 1999; Jeanes and Hilgert 2000).

Like steelhead, coastal cutthroat trout are iteroparous (i.e., do not die after spawning and return to spawn again in subsequent years). Emergence of juvenile cutthroat occurs from March to mid-July, depending on spawning date and water temperature (Trotter 1997; Johnson et al. 1999). Newly-emerged cutthroat trout are very small (<25 mm TL) and are virtually unidentifiable from steelhead. Juvenile cutthroat move immediately to low-velocity habitats where they rear for two or more years, seeking pools and other slow water habitats with root wads and large wood for cover (Trotter 1997). During the marine phase of their life cycle, juvenile and adult coastal cutthroat trout appear to utilize waters near the shore, usually in areas relatively near their natal streams (Moyle 1976; Johnston 1982; Trotter 1997). Both gravel beaches with upland vegetation, and nearshore areas containing large logs and other large woody debris are used during the marine residency phase. The life history strategy of coastal cutthroat trout is termed amphidromous, indicating individuals may enter saltwater periodically as adults, returning to freshwater to spawn (Wilson 1997).

The variety of juvenile rearing strategies expressed by Green River salmonids play a significant role in their response to restoration activities. The construction of Howard Hanson Dam interrupted the natural hydrology of the Green River and changed fish habitat below the dam. For instance, the reduction in peak river flow isolates the floodplain from the river and reduces the amount of habitat available to juvenile salmonids. The interruption of large woody debris and gravel transport from the headwaters of the Green River decreases the ability of the river to form new gravel bars, side channels, and juvenile salmonid habitat downstream from Howard Hanson Dam (Montgomery and Buffington 1998). Fish inhabiting the Green River today survived in spite of hydrology and habitat changes. From the above life history components, it is readily apparent that woody debris and gravel are essential elements of salmonid habitat in the Green River. This draft monitoring report primarily focuses on evaluating the biological response to habitat restoration measures that were constructed in Restoration Zone 1 and baseline biological information obtained from Restoration Zone 2.

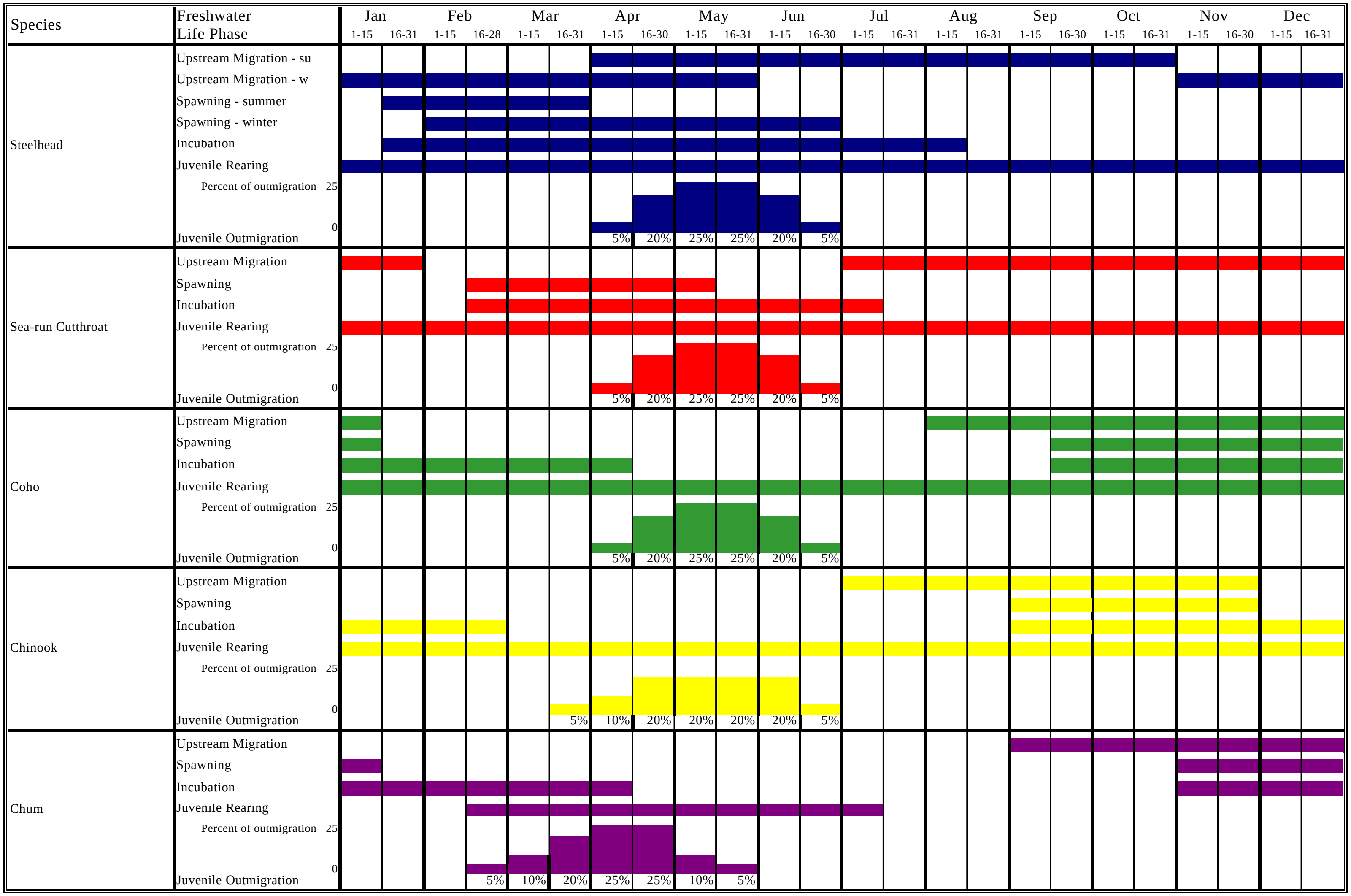

Figure 2. Temporal distribution of adult and juvenile salmonid habitat utilization in the Green River, Washington (adapted from Grette and Salo 1986; USACE 1998).

2. METHODS

The objectives of the biological surveys is to collect baseline data on juvenile and adult salmonid abundance at two sites within Restoration Zone 1 where engineered logjams were installed (treatment sites), and at two sites with habitat characteristics similar to the treatment sites, but which have not been identified for habitat manipulation (control sites). The ELJ biological monitoring included the following data modules: pre- and post construction juvenile surveys within the control and treatment sites and post-construction adult surveys within the control and treatment sites. In addition to the snorkel surveys, a post-construction fall spawner survey was conducted in 2003 that encompassed both Restoration Zone 1 and Restoration Zone 2.

2.1 SALMON SNORKEL SURVEYS

A post-treatment experimental design was used to determine the response of juvenile salmonids to ELJ construction by comparing densities at control sites to juvenile salmonid densities at treatment sites. Control sites (Figures 3 and 4) with similar habitat characteristics to the treatment sites (Figures 5 and 6) were identified prior to conducting biological surveys on 5 August 2003 in consultation with USACE personnel. Candidate control sites were initially identified using the baseline habitat survey information (TetraTech 2003b). In order to minimize the effects of non-treatment factors, control sites were located as near as possible to the treatment sites.

Each treatment and control site was delineated into a 100 linear ft reach of river channel (linear count) that encompassed the ELJ as well as a footprint site consisting of only the ELJ and immediate area surrounding it (footprint count) (Figure 7). The footprint count was included in the linear foot count but was separated to examine the influence of the ELJ structure itself on juvenile salmonid densities. Each treatment and control site was surveyed twice, once before (12 August 2003) and once after (14 October 2003) the construction of the ELJs. Pre-construction treatment sites occurred at the expected locations of the engineered logjams as indicated by design drawings (TetraTech 2003c) and flagging placed by USACE contractor personnel. Control and treatment footprint counts were delineated using an assumed ELJ footprint area of 70- X 50-ft (TetraTech 2003c).

Snorkel surveys were conducted by entering the water downstream of the selected sampling site and proceeding upstream until one complete pass was completed within the sampling site. The lateral distance between the snorkeler and the shoreline or adjacent snorkeler was based on

Figure 3. Upstream pre-construction view of ELJ Treatment Site 1 within Restoration Zone 1, upper Green River, King County, Washington, 5 August 2003.

Figure 4. Downstream pre-construction view of ELJ Control Site 1 within Restoration Zone 1, upper Green River, King County, Washington, 5 August 2003.

Figure 5. Upstream pre-construction view of ELJ Treatment Site 2 within Restoration Zone 1, upper Green River, King County, Washington, 5 August 2003.

Figure 6. Downstream pre-construction view of ELJ Control Site 2 within Restoration Zone 1, upper Green River, King County, Washington, 5 August 2003.

Figure 7. Location of treatment and control snorkel sites within Restoration Zone 1, upper Green River, King County, Washington, 21 September 2003.

underwater visibility and was adjusted at each site to ensure visual coverage of the area below and to each side of the snorkeler. Since the width of the Green River exceeds the visual capability of an individual snorkeler, each snorkeler covered separate visual lanes. The alignment and position of each snorkeler in the channel was maintained by verbal communication by an onshore observer.

Three snorkel counts occurred at each control and treatment site on each survey date. Fish were identified and reported by species and size class (fry, overyearling, and adult). The onshore observer delineated snorkel counts obtained from the footprint from those of the linear counts at each site. Observations of non-salmonids were recorded but will not be used to evaluate the effects of treatment measures. Fish abundance was calculated using the formula:

$$N = 2N_m - N_{m-1}$$

where:

N	=	fish abundance;
N_m	=	largest count; and
N_{m-1}	=	second largest count.

The bounded count methodology is used when a number of divers obtain independent counts within a site (Regier and Robson 1967). The abundance estimate was converted to a density estimate by dividing by the area of each site. The linear count estimate is inclusive of the footprint estimate; the footprint estimate was calculated to measure the number of fish within the immediate influence of the treatment (i.e., ELJ). The wetted width and length of the linear and footprint count from each control and treatment site was measured with a Bushnell® Compact rangefinder. The rangefinder was calibrated using a 500 ft tag line. Flow conditions, as measured by the USGS gage near Palmer (USGS No. 12106700), were also recorded on field notes. Water temperature to the nearest 0.5°C (measured using a handheld thermometer) and underwater visibility (measured using a Secchi disk) were recorded for each site during pre- and post-construction surveys. Pre- and post-construction photographs were taken at each control and treatment site. All data were entered electronically using MS Excel™ and cross-referenced with original field data forms for QA/QC purposes. Unless otherwise noted, all statistical analyses were performed using SigmaStat™.

2.2 SALMON SPAWNER SURVEY

The objective of the fall spawner survey was to identify the specific location of individual Chinook salmon redds so that data can be analyzed in the context of Restoration Zone 1 gravel nourishment locations and logjam placement as well as to collect baseline data for Restoration Zone 2, scheduled for construction in Summer 2004. Both of these objectives were achieved by conducting a chinook spawning survey near the peak of the 2003 fall spawning season on 15 October 2003 between RM 58 and RM 60.3 in the upper Green River (Figure 1).

The spawner survey was conducted by a team of three biologists floating in a 12 ft rubber raft, beginning at the upper site boundary (USGS Gage) and proceeding downstream to the end of the survey reach (Kanaskat-Palmer Highway Bridge). Salmon redds were marked with survey flagging tied to rocks and placed adjacent to observed redds within Restoration Zone 1. A single observer surveyed each shoreline while the third observer surveyed the deepwater portion of the channel while floating in the raft. Total spawner counts represented all live and dead fish observed within the survey reach. Longitudinal distribution of redds and spawner count data were delineated using a Garmin 76™ handheld GPS unit, USGS 7.5 minute topographical maps, and aerial photographs. While chinook were the primary species of interest, other spawning salmonids (e.g., pink and coho salmon) were identified and enumerated. Water temperature (to the nearest 0.5°C) and stage (to the nearest (0.01 ft) were recorded using a handheld thermometer and staff gage measurements, respectively. Underwater visibility, measured using a Secchi disk attached to a tag line, was used to denote the survey coverage. Representative photographs were taken of individual redds and geographical reach demarcations. All data were entered electronically using MS Excel™ and cross-referenced with original field data forms for QA/QC purposes. Unless otherwise noted, all statistical analyses were performed using SigmaStat™.

3. RESULTS/DISCUSSION

The selection of survey sites occurred before construction on 5 August 2003 whereby three survey sites were delineated by defining a footprint location (70- X 50-ft) for each ELJ structure and an associated footprint count location (90- X 70-ft) that would surround the footprint of the ELJ. In addition to the footprint count delineation, 100-ft long lineal count reach boundaries were also established at this time.

The construction of ELJ 1 and ELJ 2 as well as the gravel nourishment berms in Restoration Zone 1 was completed by 31 August 2003 (Figure 8). A total of 81 logs (with and without rootwads attached) were used to construct ELJ 1, while ELJ 2 was constructed using 88 logs (TetraTech 2003d). Two gravel nourishment berms were constructed on the left bank of the upper Green River utilizing approximately 6,082 cubic yards (Berm 1 = 2,901 yd^3; Berm 2 = 3,180 yd^3) of spawning sized gravel (TetraTech 2003d). Due to schedule constraints, ELJ 3 was not constructed in 2003.

3.1 PRE-CONSTRUCTION SNORKEL SURVEY

Pre-construction surveys were conducted on 12 August 2003 to estimate fish presence at each ELJ treatment and control site. Before ELJ construction, habitat at ELJ Site 1 was composed of both mainstem and off-channel components (Figures 3 and 4). Similar fish assemblages (i.e., species/age classes) were observed in the control and treatment sites during the pre-construction survey (Table 2). More juvenile salmonids were observed at the ELJ 1 Control Site (70.7•1,000 ft^{-2}) compared to the Treatment Site (56.1•1,000 ft^{-2}) (Table 2). Age-0+ rainbow trout were dominant (treatment = 84%, control = 95%) at both the treatment and control sites both in the lineal and the footprint counts. Mainstem habitat was the only component present during pre-construction surveys at ELJ 2; however, a similar pattern of species and abundance was observed at the ELJ 2 survey sites (Table 3). Age-0+ rainbow trout were the dominant species/age class at both the treatment and control sites both in the lineal and the footprint counts accounting for more than 73% and 98% of he total number of juvenile salmonids, respectively. Overall, juvenile salmonid abundance was lower at ELJ 2 sites (mean = 15.9 juvenile salmonids•1,000 ft^{-2}) compared to ELJ 1 (mean = 63.4 juvenile salmonids•1,000 ft^{-2}).

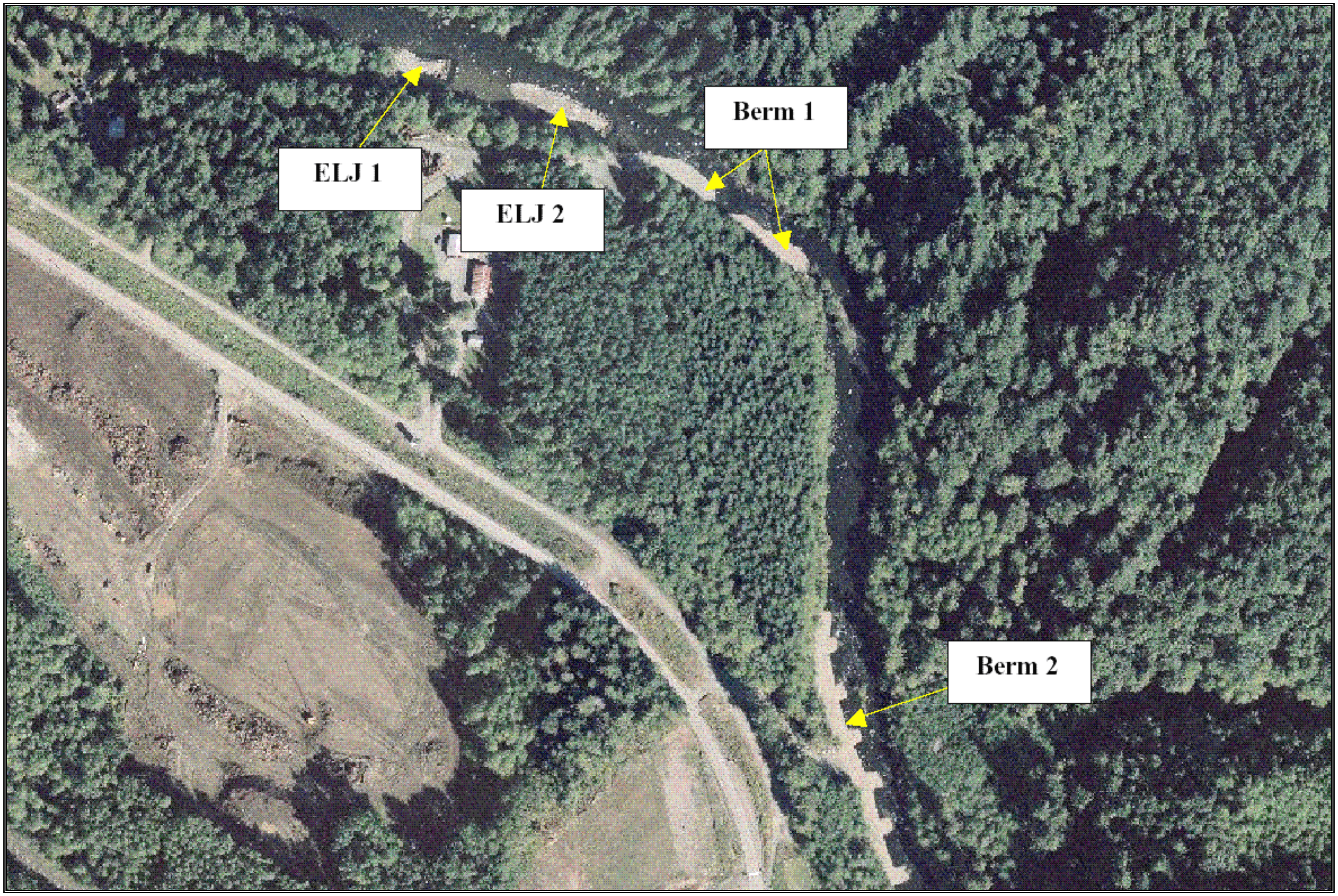

Figure 8. Location of engineered log jams and gravel nourishment berms within Restoration Zone 1, upper Green River, King County, Washington, 21 September 2003.

Table 2. Juvenile salmonid population estimates (number of fish observed•1,000 ft^{-2}) from pre-construction snorkel surveys conducted at ELJ 1, Restoration Zone 1, upper Green River, King County, Washington, 12 August 2003 (CTT = cutthroat trout, MWF = mountain whitefish, RBT = rainbow trout).

TREATMENT 1				CONTROL 1			
Species/Age	**Off Channel**	**Mainstem**	**Total**	**Species/Age**	**Off Channel**	**Mainstem**	**Total**
			LINEAL COUNT				
Age 0+ RBT	43.2	4.0	47.2	Age 0+ RBT	62.0	5.5	67.5
Age 0+ Coho	0.0	0.9	0.9	Age 0+ Coho	3.2	0.0	3.2
Age 1+ RBT	0.0	0.0	0.0	Age 1+ RBT	0.4	0.0	0.4
Age 1+ MWF	0.0	0.0	0.0	Age 1+ MWF	0.0	0.0	0.0
Age 1+ CTT	0.0	0.0	0.0	Age 1+ CTT	0.0	0.0	0.0
			56.1				70.7
			FOOTPRINT COUNT				
Age 0+ RBT	16.4	23.6	40.0	Age 0+ RBT	0.9	55.5	56.4
Age 0+ Coho	0.0	0.0	0.0	Age 0+ Coho	0.0	0.0	0.0
Age 1+ RBT	0.0	0.0	0.0	Age 1+ RBT	0.0	0.0	0.0
Age 1+ MWF	0.0	0.0	0.0	Age 1+ MWF	0.0	0.0	0.0
Age 1+ CTT	0.0	0.0	0.0	Age 1+ CTT	0.0	0.0	0.0
			40.0				56.4

Table 3. Juvenile salmonid population estimates (number of fish observed•1,000 ft^{-2}) from pre-construction snorkel surveys conducted at ELJ 2, Restoration Zone 1, upper Green River, King County, Washington, 12 August 2003 (CTT = cutthroat trout, MWF = mountain whitefish, RBT = rainbow trout).

TREATMENT 2				CONTROL 2			
Species/Age	**Off Channel**	**Mainstem**	**Total**	**Species/Age**	**Off Channel**	**Mainstem**	**Total**
			LINEAL COUNT				
Age 0+ RBT	-	15.8	15.8	Age 0+ RBT	-	9.8	9.8
Age 0+ Coho	-	5.8	5.8	Age 0+ Coho	-	0.2	0.2
Age 1+ RBT	-	0.1	0.1	Age 1+ RBT	-	0.0	0.0
Age 1+ MWF	-	0.0	0.0	Age 1+ MWF	-	0.0	0.0
Age 1+ CTT	-	0.0	0.0	Age 1+ CTT	-	0.0	0.0
			21.7				10.0
			FOOTPRINT COUNT				
Age 0+ RBT	-	87.3	87.3	Age 0+ RBT	-	67.3	67.3
Age 0+ Coho	-	1.8	1.8	Age 0+ Coho	-	0.0	0.0
Age 1+ RBT	-	0.0	0.0	Age 1+ RBT	-	0.0	0.0
Age 1+ MWF	-	0.0	0.0	Age 1+ MWF	-	0.0	0.0
Age 1+ CTT	-	0.0	0.0	Age 1+ CTT	-	0.0	0.0
			89.1				67.3

3.2 POST-CONSTRUCTION SNORKEL SURVEY

Post-construction snorkel surveys were conducted on 14 October 2003, coinciding with the expected peak of chinook salmon spawning in order to evaluate the habitat benefits of the ELJs to not only juvenile salmonids, but also adult chinook salmon. Juvenile salmonid abundance decreased at both restoration sites compared to pre-construction surveys (Figure 9). Like pre-construction surveys, more juvenile salmonids were observed at the ELJ 1 Control Site (22.1•1,000 ft^{-2}) compared to the Treatment Site (11.7•1,000 ft^{-2}) (Table 4). Unlike pre-construction surveys, footprint counts from treatment sites exceeded those collected at the control sites (Tables 4 and 5). The number of age-0+ coho salmon increased between surveys at all treatment sites (Tables 4 and 5). Overall, juvenile salmonid abundance was lower at ELJ 2 sites (mean = 3.05 juvenile salmonids•1,000 ft^{-2}) compared to ELJ 1 (mean = 16.9 juvenile salmonids•1,000 ft^{-2}).

Recent surveys conducted in the upper Green River indicate that juvenile salmonids exhibit distinct modes of emergence, residency, and downstream migration (Figure 10). The snorkel surveys that were conducted within the ELJ construction sites in 2003 were a small snapshot of the overall use of the upper Green River by juvenile salmonids. While it was impossible make statistical comparisons of use of the ELJs by juvenile salmonid (only two surveys were conducted) it is important to note that shortly after construction, juvenile salmonids (in particular age-0+ coho) were utilizing the pools and small woody debris within the rootwads that were associated with each ELJ. Future monitoring efforts should attempt to obtain an in-depth look at juvenile salmonid use of the ELJs by conducting surveys throughout the residency period of juvenile salmonids in the upper Green River.

3.3 ADULT SURVEY

Post-construction adult snorkel surveys were conducted in concert with juvenile surveys on 14 October 2003, coinciding with the expected peak of chinook salmon spawning. Adult chinook abundance was greater at both treatment sites compared to the controls (Tables 6 and 7). Chinook spawner abundance was greatest (9.1 chinook•1,000 ft^{-2}) within the ELJ 2 Treatment footprint count, where numerous chinook were holding in the deep pool associated with the woody debris (Figures 11 and 12).

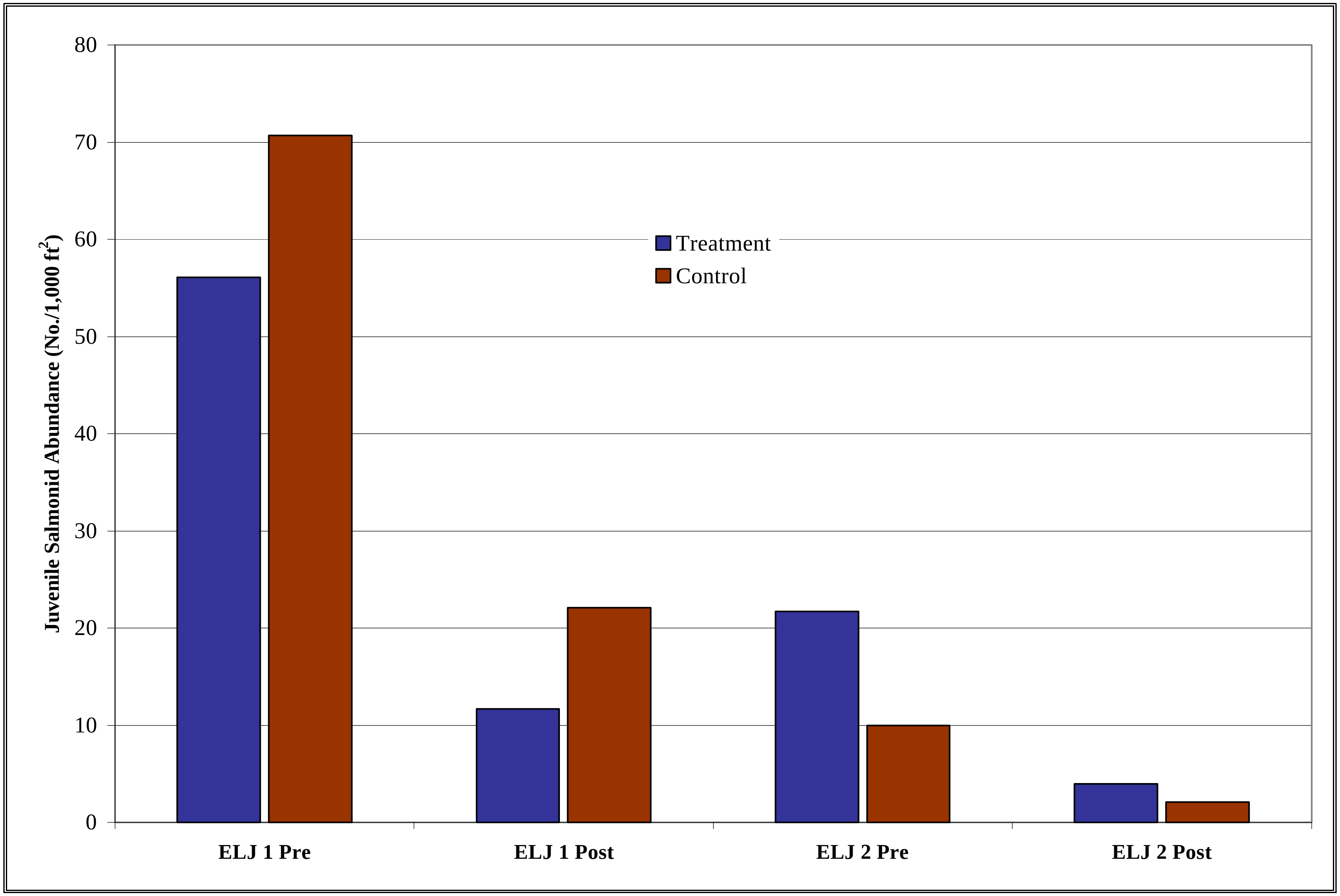

Figure 9. Pre- and post-construction juvenile salmonid abundance at engineered log lams sites in Restoration Zone 1, upper Green River, King County, Washington, 2003.

Table 4. Juvenile salmonid population estimates (number of fish observed•1,000 ft^{-2}) from post-construction snorkel surveys conducted at ELJ 1, Restoration Zone 1, upper Green River, King County, Washington, 14 October 2003 (CTT = cutthroat trout, MWF = mountain whitefish, RBT = rainbow trout).

TREATMENT 1				**CONTROL 1**			
Species/Age	**Off Channel**	**Mainstem**	**Total**	**Species/Age**	**Off Channel**	**Mainstem**	**Total**
			LINEAL COUNT				
Age 0+ RBT	3.6	3.3	6.9	Age 0+ RBT	18.4	1.8	20.2
Age 0+ Coho	0.8	1.8	2.6	Age 0+ Coho	0.4	0.1	0.5
Age 1+ RBT	0.0	0.5	0.5	Age 1+ RBT	0.4	0.2	0.6
Age 1+ MWF	0.0	1.5	1.5	Age 1+ MWF	0.0	0.8	0.8
Age 1+ CTT	0.0	0.2	0.2	Age 1+ CTT	0.0	0.0	0.0
			11.7				22.1
			FOOTPRINT COUNT				
Age 0+ RBT	8.2	31.8	40.0	Age 0+ RBT	5.5	0.0	5.5
Age 0+ Coho	1.8	18.2	20.0	Age 0+ Coho	0.9	0.0	0.9
Age 1+ RBT	0.0	3.6	3.6	Age 1+ RBT	0.0	0.0	0.0
Age 1+ MWF	0.0	0.0	0.0	Age 1+ MWF	0.0	0.0	0.0
Age 1+ CTT	0.0	1.8	1.8	Age 1+ CTT	0.0	0.0	0.0
			65.4				6.4

Table 5. Juvenile salmonid population estimates (number of fish observed•1,000 ft^{-2}) from post-construction snorkel surveys conducted at ELJ 2, Restoration Zone 1, upper Green River, King County, Washington, 14 October 2003 (CTT = cutthroat trout, MWF = mountain whitefish, RBT = rainbow trout).

TREATMENT 2				**CONTROL 2**			
Species/Age	**Off Channel**	**Mainstem**	**Total**	**Species/Age**	**Off Channel**	**Mainstem**	**Total**
			LINEAL COUNT				
Age 0+ RBT	0.5	0.2	0.7	Age 0+ RBT	-	0.2	0.2
Age 0+ Coho	0.5	1.3	1.8	Age 0+ Coho	-	0.0	0.0
Age 1+ RBT	0.0	0.0	0.0	Age 1+ RBT	-	0.0	0.0
Age 1+ MWF	0.0	1.5	1.5	Age 1+ MWF	-	1.9	1.9
Age 1+ CTT	0.0	0.0	0.0	Age 1+ CTT	-	0.0	0.0
			4.0				2.1
			FOOTPRINT COUNT				
Age 0+ RBT	0.9	0.9	1.8	Age 0+ RBT	-	1.8	1.8
Age 0+ Coho	0.0	18.2	18.2	Age 0+ Coho	-	1.0	0.0
Age 1+ RBT	0.0	0.0	0.0	Age 1+ RBT	-	0.0	0.0
Age 1+ MWF	0.0	0.0	0.0	Age 1+ MWF	-	3.6	3.6
Age 1+ CTT	0.0	0.0	0.0	Age 1+ CTT	-	0.0	0.0
			20.0				5.4

Table 6. Adult chinook population estimates (number of fish observed•1,000 ft^{-2}) from post-construction snorkel surveys conducted at ELJ 1, Restoration Zone 1, upper Green River, King County, Washington, 14 October 2003 (CTT = cutthroat trout, MWF = mountain whitefish, RBT = rainbow trout).

TREATMENT 1				CONTROL 1			
Species/Age	**Off Channel**	**Mainstem**	**Total**	**Species/Age**	**Off Channel**	**Mainstem**	**Total**
			LINEAL COUNT				
Adult Chinook	1.6	0.7	1.3	Adult Chinook	0.0	0.0	0.0
			FOOTPRINT COUNT				
Adult Chinook	0.0	0.0	0.0	Adult Chinook	0.0	0.0	0.0

Table 7. Adult chinook population estimates (number of fish observed•1,000 ft^{-2}) from post-construction snorkel surveys conducted at ELJ 2, Restoration Zone 1, upper Green River, King County, Washington, 14 October 2003 (CTT = cutthroat trout, MWF = mountain whitefish, RBT = rainbow trout).

TREATMENT 2				CONTROL 2			
Species/Age	**Off Channel**	**Mainstem**	**Total**	**Species/Age**	**Off Channel**	**Mainstem**	**Total**
			LINEAL COUNT				
Adult Chinook	6.8	0.0	6.8	Adult Chinook	0.0	0.1	0.1
			FOOTPRINT COUNT				
Adult Chinook	9.1	0.0	9.1	Adult Chinook	0.0	0.0	0.0

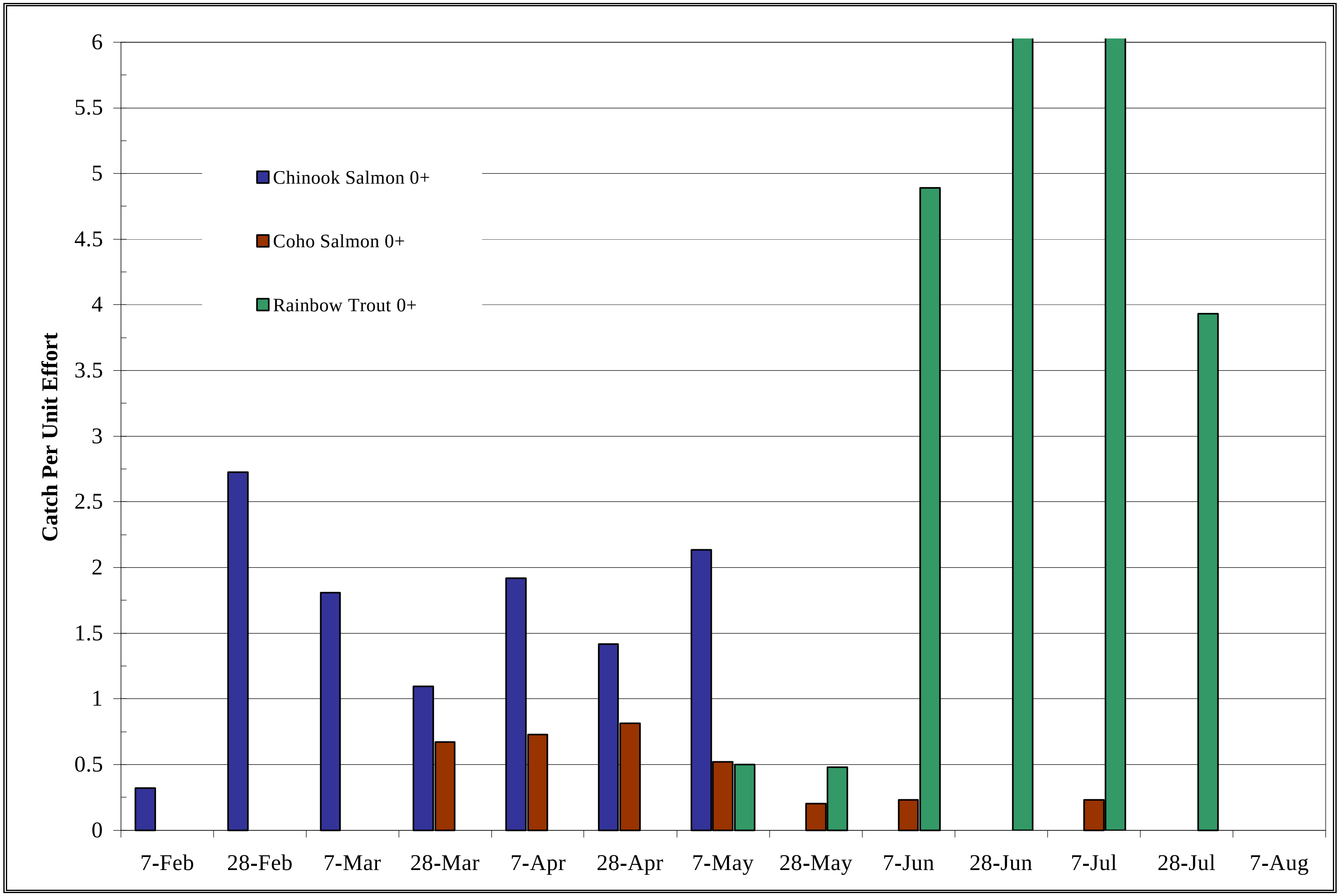

Figure 10. Age-0+ chinook and coho salmon, and rainbow trout catch-per-unit-effort indices collected during juvenile salmonid surveys conducted in the upper Green River, King County, Washington, 2000-2002.

Figure 11. Downstream post-construction view of ELJ 1 within Restoration Zone 1, upper Green River, King County, Washington, 14 October 2003.

Figure 12. Downstream post-construction view of ELJ 2 within Restoration Zone 1, upper Green River, King County, Washington, 14 October 2003.

3.4 SPAWNER SURVEY

A total of 73 adult salmon (5.0 salmon•1,000 ft^{-1}) were observed during spawner surveys conducted on 15 October 2003 in the upper Green River (Table 8). The spawner survey encompassed the upper Green River beginning at the USGS Gage Site, downstream to Kanaskat-Palmer Highway Bridge (Figure 1; see Appendix Figures A-1 – A-8 for chinook salmon redd locations in fall spawner survey reach). Chinook salmon were the most abundant species, accounting for more than 79% of the live fish, 98% of the carcasses, and 87% or the redds that were observed. The number of spawning salmon (32.3 salmon•1,000 ft^{-1}), carcasses (61.5 carcasses salmon•1,000 ft^{-1}), and redds (41.5 redds salmon•1,000 ft^{-1}) was greatest within Restoration Zone 1 compared to downstream reaches of the upper Green River (Table 8; Figure 13). Restoration Zone 2 accounted for the second highest density of spawners (20.0 salmon•1,000 ft^{-1}), redds (38.7 redds•1,000 ft^{-1}), and carcasses (9.3 carcasses•1,000 ft^{-1}) in the upper Green River during 2003 (Table 8; Figure 14).

The Washington Department of Fish and Wildlife (WDFW) conducts periodic spawning surveys of the upper Green River (S. Pozarycki, USACE, pers. comm.; Malcom 2002). Chinook redd density (3.8 redds•1,000 ft^{-1}) observed in this study was lower than the average chinook redd density observed in the upper Green River from 1997-2000 by WDFW (7.4 redds•1,000 ft^{-1}). However the 1997-2000 density is a cumulative over the entire spawning period and our estimate is a single observation from the peak of the spawn timing. The chinook redd densities observed in Restoration Zone 1 compare favorably to densities obtained from the highest concentration of chinook spawners on the Green River (Malcom 2002). Future restoration monitoring efforts should attempt to capture the entire chinook spawning window in the upper Green River. Three survey occasions commencing in late September and continuing through the end of October should adequately define the temporal distribution of chinook spawning in this reach of the river.

3.5 RECOMMENDATIONS

Extensive modifications of watersheds for municipal water supply, hydroelectric production, flood control, irrigation, navigation, and other diversions have permanently changed the physical and integrity of many Pacific Northwest river systems (Wissmar and Bisson 2003). The recent listing of various stocks of Pacific salmon under the Endangered Species Act has focused the national attention on the conditions of rivers and streams in the Puget Sound advancing river restoration and ecosystem function. Restoration as defined by the National Research Council (1992) is the reestablishment of the structure and function of an ecosystem, including its natural integrity. Restoration of ecosystem structure should provide a healthy and functioning watershed and riverine system (Williams et al. 1997). Attempts to restore river habitat and function using large woody debris (Dominguez and Cederholm 2000) and sediment nourishment (USFWS and Hoopa Valley Tribe 1999) already appear to have been successful in support of Pacific Salmon. The upper Green River has been separated from its supply of sediment and woody debris since the completion of Howard Hanson Dam in 1962. Large woody debris influences coarse sediment storage, increases habitat diversity and complexity, and provides refugia for aquatic organisms during high and low-flow events (Bisson et al. 1987). An alluvial river can function properly only if continuously supplied with material. The installation of Engineered Log Jams and gravel nourishment berms in the upper Green River is an effort to enhance these and other habitat factors for native salmonid populations. Often times the information and levels of certainty needed to guide restoration processes fall short of scientific standards which leads to indecisiveness on the part of decision makers (Ryan and Jensen 2003). While this study was preliminary in nature, it does suggest that various species and life stages of salmonids will utilize restoration zones in the Green River. Future monitoring efforts should attempt to tease out the level of increased production that may be attributed to restoration processes. In an effort to show ecosystem response, biological monitoring could be extended to macroinvertebrates as well as fish species other than salmonids (Kauffman et al. 1997). At a minimum, juvenile salmonid surveys should occur throughout the periodicity of residence for coho and chinook salmon, and rainbow trout. Spawner surveys should capture the entire chinook spawning period instead of just the peak of spawn timing.

Table 8. Reach delineation, species, and total number of live, dead, and redds observed during spawner survey conducted in upper Green River, King County, Washington, 15 October 2003.

Zone	Reach Length (ft)	Species	Live Fish	Carcasses	Redds
RESTORATION ZONE 1					
	650	**Chinook**	16	38	23
		Coho	1	0	0
		Pink	4	2	4
		Sub-total	21	40	27
		No.•1,000 ft^{-1}	***32.3***	***61.5***	***41.5***
RESTORATION ZONE 2					
	750	**Chinook**	10	29	4
		Coho	0	0	0
		Pink	5	0	3
		Sub-total	15	29	7
		No.•1,000 ft^{-1}	***20.0***	***38.7***	***9.3***
NON RESTORATION ZONES					
	13,250	**Chinook**	32	190	28
		Coho	0	0	0
		Pink	5	3	1
		Sub-total	37	193	29
		No.•1,000 ft^{-1}	***2.8***	***14.6***	***2.2***
GRAND TOTAL					
	14,650	**Chinook**	58	257	55
		Coho	1	0	0
		Pink	14	5	8
		Total	73	262	63
		No.•1,000 ft^{-1}	***5.0***	***17.9***	***4.3***

Figure 13. Location of chinook salmon redds (N=23) in Restoration Zone 1, upper Green River, King County, Washington, 15 October 2003.

Figure 14. Location of chinook salmon redds (N=4) in the proposed Restoration Zone 2, upper Green River, King County, Washington, 15 October 2003.

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Howard Hanson Dam

Additional Water Storage Project Phase 1

Habitat Restoration Zone One Biological Monitoring

Appendix A

Chinook Salmon Redd Locations

Figure A-1. Location of chinook salmon redds in the fall spawner survey reach of the upper Green River, King County, Washington, 15 October 2003 (solid red lines = survey reach boundaries; dashed red lines = sub-reach boundaries).

Figure A-2. Location of chinook salmon redds in sub-reach of the upper Green River, King County, Washington, 15 October 2003.

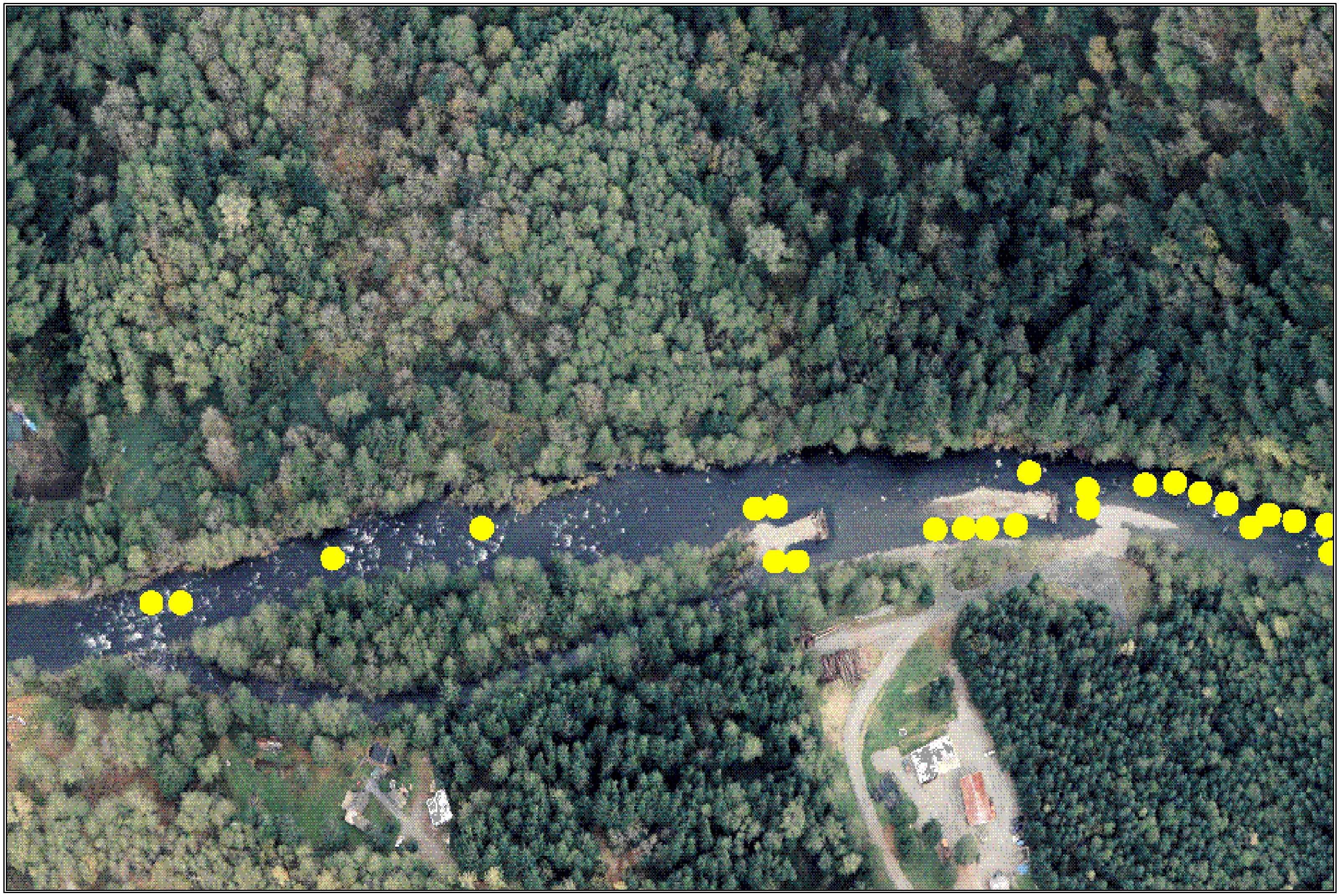

Figure A-3. Location of chinook salmon redds in sub-reach of the upper Green River, King County, Washington, 15 October 2003.

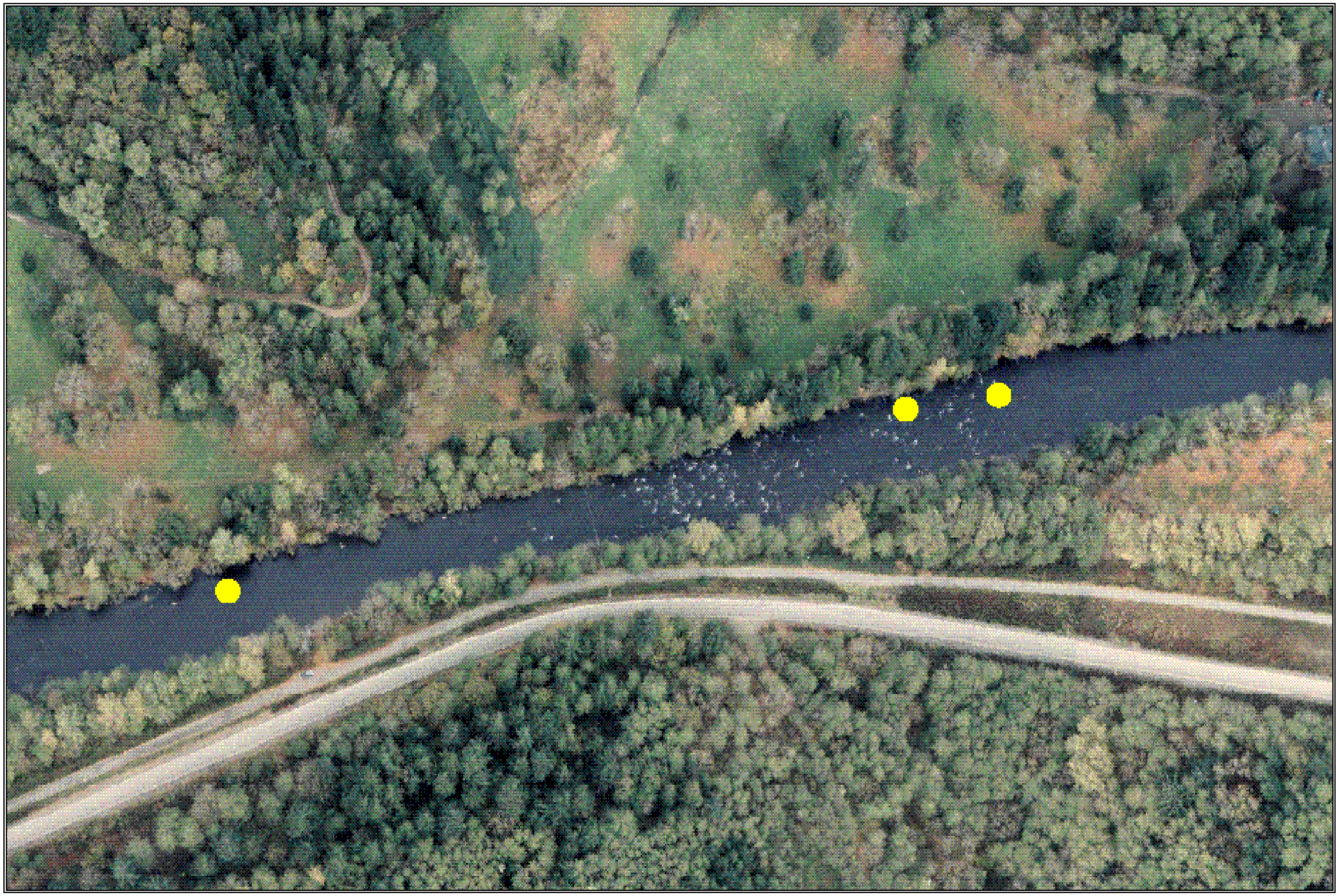

Figure A-4. Location of chinook salmon redds in sub-reach of the upper Green River, King County, Washington, 15 October 2003.

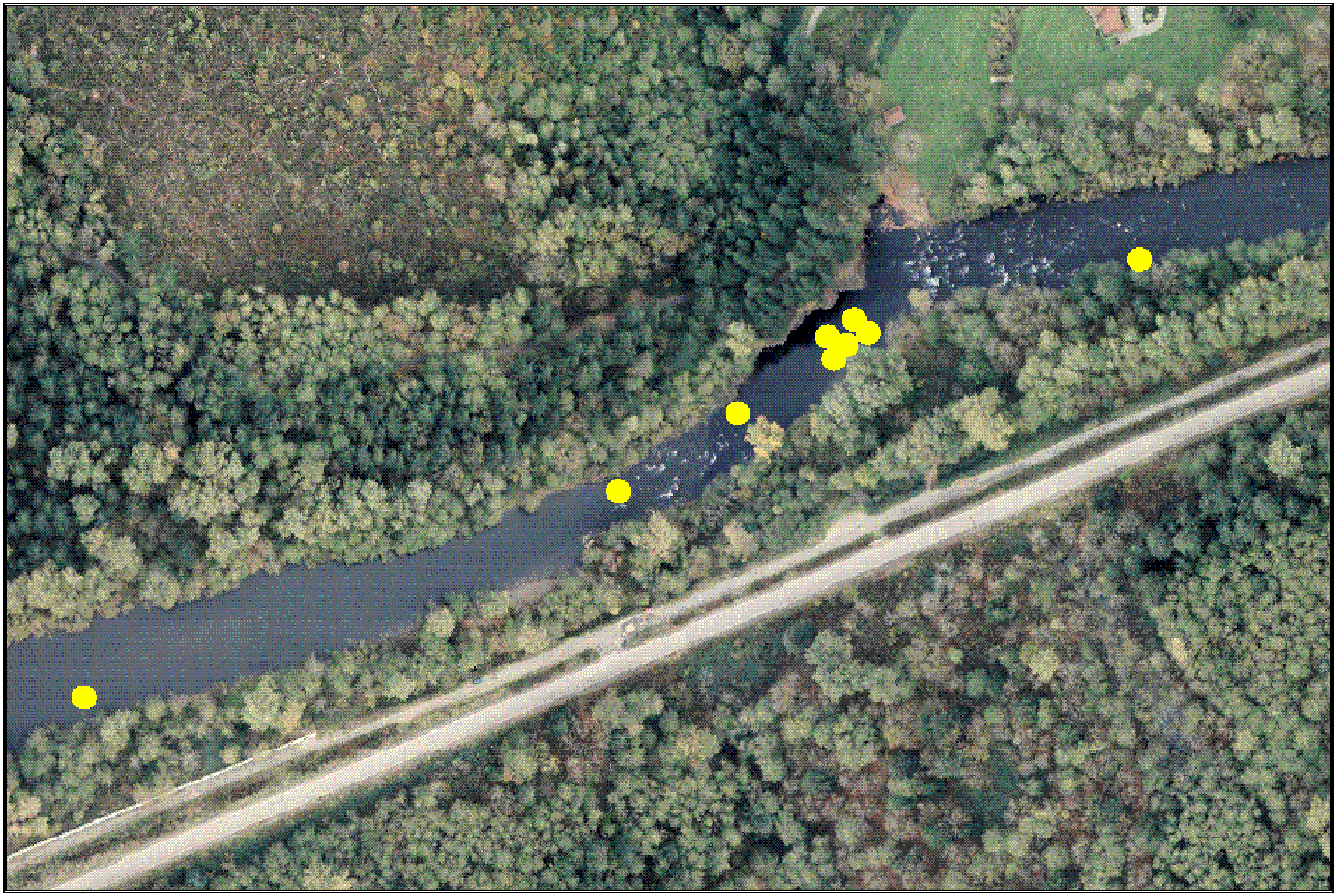

Figure A-5. Location of chinook salmon redds in sub-reach of the upper Green River, King County, Washington, 15 October 2003.

Figure A-6. Location of chinook salmon redds in sub-reach of the upper Green River, King County, Washington, 15 October 2003.

Figure A-7. Location of chinook salmon redds in sub-reach of the upper Green River, King County, Washington, 15 October 2003.

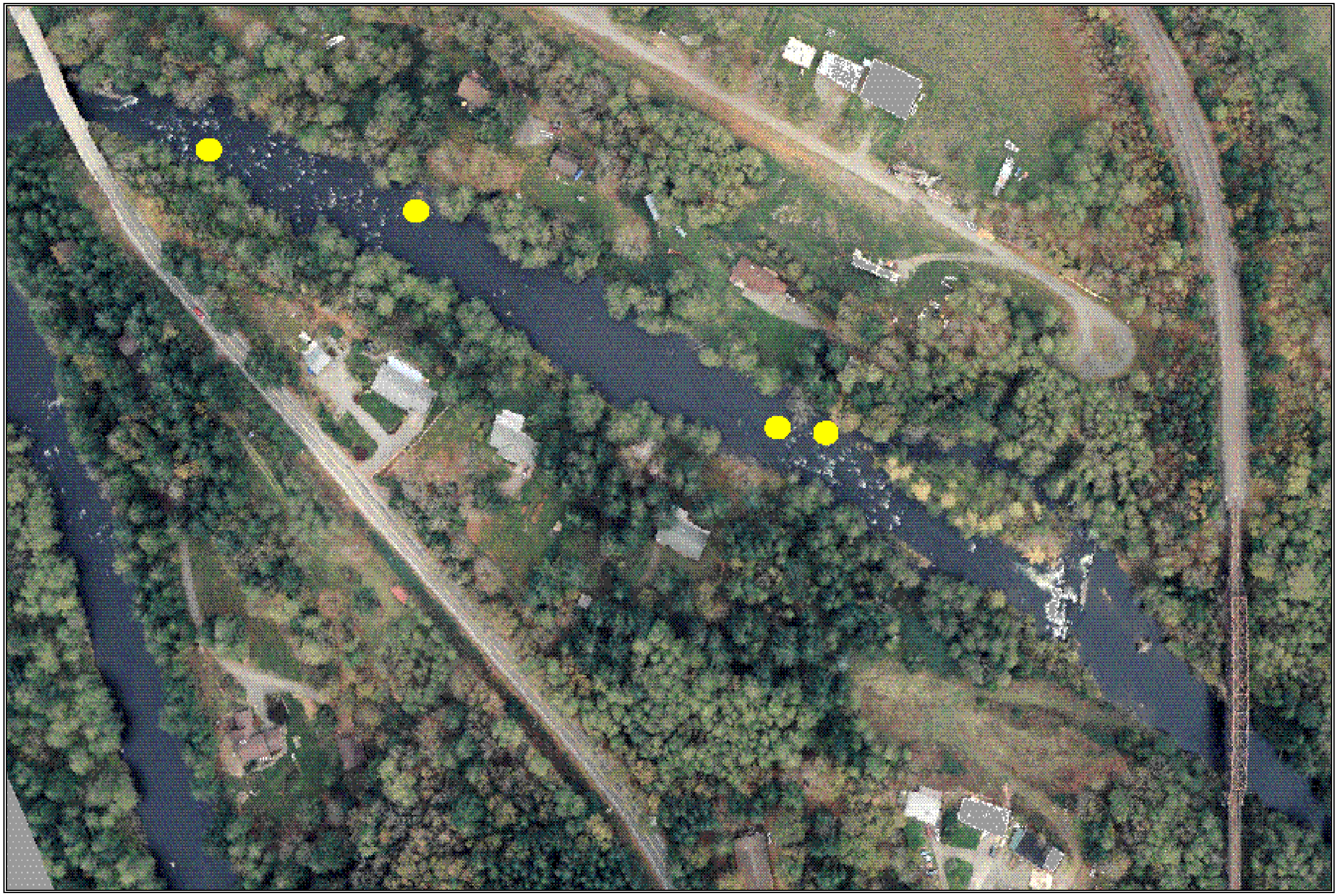

Figure A-8. Location of chinook salmon redds in sub-reach of the upper Green River, King County, Washington, 15 October 2003.